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THE ADAPTATION OF CPR TECHNIQUES FOR USE IN THE WEIGHTLESS ENVIRONMENT

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Introduction:

Many Advanced Cardiac Life Support (ACLS) techniques, including standard Cardiopulmonary Resuscitation (CPR) as currently performed on earth, cannot be successfully executed in the weightlessness of space. In fact, recent studies have cast doubt on the effectiveness of standard CPR even on earth. Therefore, in order to effectively deal with the eventuality of cardiac arrest in space and to determine the optimum resuscitation techniques for both the earth and space environments, we have proceeded with an assessment of the state-of-the-art and made suggestions for further work.

Background:

There is a need for developing the capability to perform effective and efficient CPR for use in space. The hazards of electrocution, hypoxia, decompression, trauma, and toxic exposure are present as potential sources of injury from which a healthy astronaut might recover if properly resuscitated and supported. There is the eventuality of a cardiac arrest in space as horizons expand and more and more people of all ages and physical conditions arrive. Finally, it is important to plan now for a future in space which will allow the propagation of standards of medical care and lifestyles equivalent to those we now enjoy on earth.

A number of factors render conventional CPR useless in the space environment: a lack of smooth hard surfaces to stabilize the victim against; the absence of rescuer weight to convert into driving force in the administration of CPR; the need for immediate attention to, and correction of, any possible spacecraft malfunction which may have caused the arrest; and the lack of large numbers of bystanders to carry out CPR.

The technique for CPR in space will have the following requirements: provision of adequate perfusion/oxygenation during resuscitation; compact size and minimum mass for associated materials or constructions; easy application and use by nonmedical personnel; some degree of automation to allow crewmembers to attend to other immediately pressing duties during prolonged periods of support; the integration of ventilation, perfusion, monitoring, IV therapy, and other resuscitative modalities into one intact unit.

The current standard of CPR employs closed chest massage, a technique first described by Boehm in 1878 but not widely used until 1960 when Kouwenhoven, Knickerbocker, and Jude presented their landmark study in JAMA, demonstrating its utility (4). This is combined with any of several forms of direct airway ventilation, the efficacy of which was shown in the 1950's (9).

Original conjecture has been that CPR "works" by compression of the heart between the sternum and the vertebral column. A variety of studies (3) have now shown that increases in intrathoracic pressure are responsible for perfusion during CPR, and perfusion can be maintained with very little direct compression of the sternum. It appears that the increased pressure is transmitted out the aorta but collapses the great veins resulting in forward flow. These studies are corroborated by the following findings: the valves of the heart are incompetent and the volume of the left ventricle does not change significantly during standard CPR as measured by 2-D echocardiogram (8). Further indication that intrathoracic pressure fluctuations are the mechanism of perfusion is the fact that consciousness has been maintained in cardiac arrest patients (induced inadvertently during cardiac catheterization) for up to one minute by coughing. The intrathoracic pressure increases are directly related to each cough (2).

Studies recently in animal subjects using standard CPR found that the blood flow to the coronary arteries during resuscitation was poor due to inadequte perfusion pressure (12 mmHg vs. a requirement of 28 mmHg for significant flow to occur) (7). Obviously, the standard method of resuscitation is in need of some refinement. Some work has been done along these lines. Researchers have demonstrated that simultaneous ventilation and chest compression along with abdominal binding provides a useful modification (6). In addition, the use of pneumatic vest CPR to create fluctuations in intrathoracic pressure was found to produce improved survival in an animal model compared to conventional CPR (7 of 9 vs. 1 of 9). It is of import that the pneumatic vest causes virtually no rib fractures and their accompanying complications. The vest technique requires an automated inflation mechanism for the proper timing of all events. Another automated device, the Thumper, is available but it functions in the same inefficient manner as conventional CPR, directly displacing the sternum and thereby creating a risk of rib fracture complications.

A New Study :

Initial trials of a chest enclosure using pneumatic bladders by Drs. Loyd, Rosborough, and Tipton are showing promise. While previous dog studies have demonstrated the superiority of pneumatic vest CPR to thumper or conventional CPR, the results could not be directly extrapolated to humans because of the much lower chest compliance in man. Therefore, the animal model selected was swine due to similarities between swine and human chest compliance (5). Ten swine subjects were fibrillated and randomized into control (no pumping) and experimental (pumping) groups. The initial studies have demonstrated systolic pressures of up to 170 mmHg., as well as significant blood flows indicated by dye injection.

Discussion :

The current technique for CPR in space involves placing the victim in the Shuttle seat and strapping the rescuer on top; compression is then achieved by the rescuer forcing his body against the victim's chest. It is unknown what perfusion pressures this produces but assumed to be similar to conventional CPR, since it relies on sternal compression (1). The current information suggests that a device or technique should be developed which can maximize intrathoracic pressure fluctuations to produce adequate perfusion of vital organs and allow venous return for continued perfusion, while not increasing but perhaps even lessening the risk of injury. In this regard an enclosed pneumatic compression device would be superior to any form of direct compression. It is also true that such a device can be adapted to fulfil the requirements of: prolonged or intermediate duration life support independent of other personnel, ease of application and use, and integration into a single intact total life support/ICU type unit.

Summary:

1) If people are to live and work permanently in space as on earth, the standards of earth medical care, such as CPR, need to be adapted for use in space.

2) The development of an automated, integrated, pneumatic CPR device could fill this need.

3) This technology may result in improved CPR techniques here on earth which could save many lives, further demonstrating the benefits of space exploration.

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